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Key conclusions of the workshop on hydrofluorocarbon management: technical issues

Summary by the rapporteurs¹

I. Background

1. In paragraph 2 of decision XXVI/9, the parties to the Montreal Protocol on Substances that Deplete the Ozone Layer decided to convene a two-day workshop, back-to-back with an additional three-day Open-ended Working Group meeting in 2015, to continue discussions on all issues in relation to hydrofluorocarbon (HFC) management, including a focus on high-ambient temperatures and safety requirements, as well as energy efficiency, taking into account the information requested in the decision and other relevant information. The workshop was held in Bangkok on 20 and 21 April 2015 and involved the wide participation of technical experts and industry representatives as overview speakers, panellists and participants, thereby enabling technical clarifications to be made, with in-depth discussion at the practical level. As a basis for the discussions, fact sheets on the status of the application of HFCs and their alternatives for the various industry subsectors were made available prior to the workshop. The fact sheets were prepared by the Secretariat with the help of experts and were widely peer-reviewed by experts within the Technology and Economic Assessment Panel and its relevant technical options committees.

2. The present summary sets out the key issues discussed at and the conclusions of the six sessions of the workshop, as summarized by the rapporteurs, for further consideration by the parties at the additional three-day Open-ended Working Group to be held in Bangkok from 22 to 24 April 2015.

II. Overview

A. Foreword

3. Today it has become more urgent to address climate issues in an increasingly holistic way and to integrate climate considerations across many levels of decision-making, not only in the context of the Montreal Protocol but also across the future development chain, independent of a particular regional perspective.

¹ The rapporteurs were Ms. Karin Shephardson, World Bank, and Mr. Stephan Sicars, United Nations Industrial Development Organization.

4. The implementation of the Montreal Protocol has led to a number of impacts on the climate, many of which have been positive but some which have been negative. These need to be better understood and taken into account with a view to minimizing negative effects where feasible. The determination of feasibility, however, is complex, and has different dimensions, including financial, technical, geographic and social dimensions, which are either relatively easy or more difficult to deal with and can have either more or less clarity, depending on whether issues are better or less understood.
5. There is recognition of the importance of holding such workshops and events in order to continually update and exchange information on the experience of others and how the test of feasibility is being interpreted in different operating conditions.
6. One of the greatest challenges in this field of very specialized experts is to put things in simple enough terms so that information can be exchanged in a meaningful way. As the range of possible solutions necessarily broadens, so does the range of actors and decision makers involved, and thus there is a need to continually work at simplification and synthesis of information to keep everyone up to date.
7. In this context, one of the most significant contributions of the workshop has been the development of fact sheets, undertaken by the Ozone Secretariat according to a rigorous peer review process, distributed among participants in the workshop even before its opening. This helped to provide a backbone for the discussions, focusing current knowledge on very few pages and thus representing a significant step forward in forging a common understanding. The workshop truly came alive through the excellent organization and preparation by the Ozone Secretariat and its consultants, the outstanding facilitators, the knowledgeable overview speakers and panellists, the excellent session rapporteurs and, last but not least, the engaged and interested audience.

B. HFC use and emissions

8. Since 1990, HFC production and consumption have been growing rapidly, mainly owing to the fact that HFCs have traditionally been used as the main replacements for ozone-depleting substances in many applications. In global-warming-potential-weighted terms, HFC demand data shows that 86 per cent of the use is in the refrigeration and air-conditioning sector, dwarfing demand in the foam sector (7 per cent) and other sectors (7 per cent) in the 2012–2014 period. Looking at total HFC demand in terms of global-warming potential (GWP)weighted amounts, three subsectors are particularly prominent: air-to-air air conditioning, at 25 per cent, commercial refrigeration, at 22 per cent, and mobile air conditioning, at 20 per cent of GWP-weighted total HFC demand.
9. Demand for HFCs has grown by 10 to 12 per cent per year in non-Article 5 countries over the period 2001–2011 (post-2014 growth is estimated at 1 to 3 per cent per year), whereas demand increased more than 30 per cent annually in Article 5 countries during the period 2006–2011 and is expected to rise further, with growth expected to be in the 5 to 7 per cent range after 2016. Regulations already approved (for example, European Union F-gas regulation 517/2014) or being considered (for example, in Japan and the United States of America) could affect future demand.
10. Growth in HFC production and consumption is reflected in the rapid increase in the atmospheric abundance of HFCs, which are still very small (approximately 20 per cent of the current CFC-12 abundance). Atmospheric observations show that HFC emissions are increasing in line with projections (for example, emissions above 250 million tonnes of CO₂ equivalent in 2013), with the fastest growth rate observed in developing countries not required to report on greenhouse gas emissions under the United Nations Framework Convention on Climate Change. Emission projections for various geographical regions and usage sectors are becoming available.¹ Under business as usual scenario, radiative forcing due to HFC emissions in 2050 could be as high as 25 per cent of that of future CO₂ emissions.

III. Technical aspects

11. HFCs are currently used in a number of market sectors and subsectors. The workshop fact sheets describe these in detail, including for 10 main markets and at least 30 subsectors.
12. Low-GWP alternatives to HFCs are already being used on a commercial scale in a number of geographic regions and in a number of subsectors. In the refrigeration and air-conditioning sector, this is the case for domestic refrigeration, commercial refrigeration (stand-alone equipment and centralized

¹ Velders and others (2015) (forthcoming).

systems), industrial refrigeration, transport refrigeration, small self-contained air conditioning, small split air conditioning, chiller systems, heating-only heat pumps and mobile air conditioning (cars). Low-GWP alternatives to HFCs are also available on a commercial scale in foam and aerosol applications.

13. Some of these commercially available alternatives to HFCs are not widespread but are limited to certain geographic markets and regions (for example, centralized commercial refrigeration systems). It was pointed out that disparate national standards in industrialized countries lead to differences in technology and approach and therefore to a longer time scale until one technology emerges as leading candidate. Examples were the use of hydrocarbons in domestic refrigeration and the introduction of HFO-1234yf in the mobile air-conditioning sector. Further details on HFCs in each sector can be found in the annex to the present summary.

14. Low-GWP alternatives to HFCs are currently at either the demonstration or feasibility study stage in the following refrigeration and air-conditioning subsectors: commercial refrigeration (condensing units), larger split air conditioning and other types of air-to-air systems, and mobile air conditioning (larger vehicles).

15. Prospects regarding the market introduction of low-GWP alternatives in 2020 and beyond will be strongly influenced by the demand volume, as economies of scale are important at various levels. Of particular importance are the production volume of low-GWP alternatives (and the related impact in terms of costs), innovative system design and the availability of adequate system components. In principle, the higher the investment cost to introduce a new low-GWP alternative, the more difficult the market introduction will be.

16. The main barriers to the adoption of alternatives in the refrigeration and air-conditioning sector include investment costs, in combination with a lack of regulatory requirement for change, the availability of components, technician training and the lack of or limitations within safety standards.

17. The refrigeration and air-conditioning subsectors need to be assessed individually in order to evaluate options for HFC alternative technologies and methods for reducing HFC consumption through: (a) the use of alternatives in new or existing equipment; (b) leak minimization; or (c) recovery and reuse of HFCs.

IV. Cross-cutting challenges and opportunities

18. During the workshop, several common issues emerged across almost all alternative technology discussions. Concern about uncertainty over costs, appropriate burden-sharing arrangements and a shared desire for cost-effective options have historically been part of the Montreal Protocol, while other issues are new. In general, cost and financial needs are diversifying as technology options widen and climate issues grow in importance.

19. **Energy efficiency.** In the context of the discussion on energy efficiency, it was highlighted that more relevance is given nowadays to synchronizing a move away from HFCs in the refrigeration and air-conditioning sector, with co-investments in energy efficiency or green building construction and technology upgrades. Many participants in the workshop called for a more holistic use of life-cycle analysis tools to make decisions on technology choice, taking into account the CO₂-equivalent reduction potential of the low-GWP alternative and its impact on energy use. Refrigeration and air-conditioning systems upgrades solely for the purpose of improving energy efficiency are also under way outside the Montreal Protocol. Given this, there is a more immediate need to introduce longer-term lower-GWP options quickly to integrate these with concurrent energy investments.

20. **Costs and intellectual property rights.** Costs were one of the cross-cutting themes discussed during the workshop as being an important barrier to the transition to low-GWP alternatives. There were several case examples demonstrating why we should not look only at capital costs as a single measure of cost-effectiveness, as operating and other costs may be more significant. Many of the panellists stated that the initial cost differential between existing solutions and new solutions were in the range of a 15–20 per cent, in some cases because of the lack of magnitudes of scale, in others because of patents introduced for development cost recovery. Intellectual property rights and restrictions resulting from patents created to positively stimulate innovation through research and development can in turn add to the burden of costs and limit the pace of important technology transfer. While these issues have been with the Montreal Protocol since its inception, some more limited patent-sharing has occurred. It remained unclear to what degree the Multilateral Fund would be able to address those issues. New approaches may be required to facilitate quicker and more economical technology transfer, especially in sectors where there are less feasible alternative choices.

21. Some of the sector-specific sessions emphasized that, where profit margins were fairly low, cost increases associated with new technologies played an important role in deciding which technology options were ultimately more widely adopted. Initial start-up costs were also considered by some to be a key barrier to a quicker entry into the market. Uncertainty about which technologies would eventually dominate in the market was also noted as keeping some industries from expanding alternative solutions more rapidly. The establishment of regulatory and policy direction would allow early adopters to invest with confidence in new technologies, despite initial higher costs, and create the necessary momentum to drive down cost.

22. **Safety and flammability.** Moving away from higher-GWP HFCs and towards lower-GWP alternatives leads to the emergence of issues related to the flammability of a number of alternatives. Concerns regarding safety and handling were voiced; the adoption of some of the options would require significant redesign of equipment, upfront investment in training and capacity-building, and behavioural changes. Some of the upfront capital costs for safety equipment are prohibitive to small and medium-sized enterprises that are interested, in particular, in transitioning to low-GWP technology. Many current safety standards, based on decades of use of non-flammable technologies in the sectors, appear to restrict alternatives. These would need to be revisited and possibly revised and updated to describe proper operating conditions and safety measures as necessary.

23. **High ambient temperatures.** High ambient temperatures appear to play only a limited role in the selection of alternatives to HFCs in the refrigeration, mobile air-conditioning and foam sectors, but are important when selecting alternatives for air-conditioning equipment. High-ambient-temperature countries are highly dependent on air conditioning to maintain productive living. At the same time the larger temperature difference between inside and outside creates special challenges for any air-conditioning equipment in terms of high cooling demand, system capacity and energy efficiency. The higher cooling demand, together with the resulting system size increase, creates challenges in the uptake of, in particular, technologies using flammable substances. Since the air-conditioning market in such countries employs larger units for a given cooling task, flammable alternatives will be limited to a smaller share of the market compared with other countries. Not-in-kind solutions, such as district cooling systems, can be considered to contribute to some degree to HFC use reductions in higher ambient climates. However, it was recognized that there may be other limitations, such as water supply constraints.

24. **Policy and regulatory frameworks.** The policy and regulatory framework plays an important role in helping to signal technology alternatives. Panellists found that the European Union F-gas regulation in particular should be credited for influencing the development of alternatives in the mobile air-conditioning and commercial/supermarket refrigeration sectors. Industry panellists reflected that the signal inherent in legislation spurred more innovation and faster movement to lower-GWP alternatives and towards market penetration than they had expected, even in the case of higher costs for the alternative technology. It was also mentioned that the lead times to adapt to legislative signals were in the order of 5–15 years, including the necessary technology development time, depending on the sector. Early signals providing industry with a secure framework for their planning, development and marketing were important.

25. **Service sector and training needs.** Participants in both the refrigeration and air-conditioning sessions advised that the current skill level of technicians in the service sector, in particular in Article 5 countries, was insufficient for handling flammable or high-pressure refrigerants. The selection, design, installation and service of new technologies were likely to be more complex than current technologies, with a particular need for education on safety-related requirements. A need existed to formalize the currently often informal – or not at all – organized service sector and to advance standards for the servicing of equipment and training materials. Such efforts would at the same time improve the quality of service and, indirectly, reduce emissions during operation and service.

26. **Special challenges for Article 5 countries.** Article 5 countries face special challenges. Their ongoing hydrochlorofluorocarbon (HCFC) phase-out efforts are constrained by the limited readiness of new alternative low-GWP technologies when needed for their HCFC phase-out schedule. This challenge means that they might face some more difficult short-term choices and higher initial transition costs when they move new products onto the market and that, in some cases, they might face double transitions. All of those considerations discourage a transition away from HCFCs, while the ongoing needs of the transition occupies technical resources needed for assessment, research, development and training related to HFC alternatives. Best opportunities exist for green-field investments where more holistic designs, including refrigerant alternatives, can be considered right from the start.

27. Low-volume consuming countries face special challenges as technology "takers". They need to trust that replacement technologies will perform in their climatic, social and capacity constrained conditions. On the more positive side, there may be greater opportunities for innovation and expanding the use of not-in-kind replacement solutions, especially those amenable to off-grid solutions using renewable resources like solar. One of the most significant actions that low-volume consuming countries can take to reduce HFC emissions in the shorter term is to focus on strengthening the servicing sector to improve maintenance quality and reduce leakage rate in the existing equipment stock, possibly convert, in particular, R-404A equipment to alternatives, and improve recycling and reclamation programmes addressing refrigerant recovery during service and at end of life.

V. Key take-away messages

A. Alternative solutions in almost all sectors

28. Alternative solutions in almost all sectors have been developed, primarily in non-Article 5 countries, where recent policy signals have helped drive technological innovation. A range of alternatives in the foam sector are available or are becoming available in the market, depending on application and user, despite some challenges. To a lesser degree, the commercial refrigeration sector and small and large industrial refrigeration sectors also have commercialized options, although in that regard more work is required to cover the full range of applications and to permit their global use in all climates and regions.

29. In the air-conditioning sector the situation is more diverse. There are a number of alternative technologies available for chillers, and there is also movement towards lower-GWP alternatives for small self-contained air-conditioning systems. Medium-sized air-conditioning systems, however, are subject to challenges in the identification of suitable substitutes. One possible contribution to solve the problem would be to change systems towards the broader use of chillers. Another might be the use of mildly flammable refrigerants for smaller to medium-sized systems; however, a clear path forward could not be provided. This is especially pronounced for high-ambient climates, where air conditioning is essential and large- and medium-capacity systems are prevalent in particular. However, many examples were provided showing how lower-GWP options for all uses in principle might be adapted to the highest ambient conditions.

B. Accounting for energy efficiency

30. Energy efficiency is one of the key aspects to be considered in any refrigeration and air-conditioning system. The climate impact of such systems is related not only to the emissions of the refrigerant but also to energy consumption. Life-cycle analysis could be used as a tool to better account for these benefits.

C. Need to be adaptive and flexible

31. Many participants in the workshop highlighted the need to be adaptive and flexible. HFC-consuming sectors are currently in a transition period, with new options and technologies being tested and experimented with in several regions. The workshop provided examples of how the landscape for assumed best alternatives was dynamic and changing or broadening in a relatively short time frame, for example in the mobile air-conditioning sector. Patents on new alternatives have spurred the development of other options; thus, they could both be helpful and introduce cost barriers. Given the collective need for action, more creative solutions might be needed to balance these trade-offs.

D. Lessons on penetration and the transfer of new technologies to new markets

32. Adaptation and readiness actions are needed to enable new technologies to be adopted in new markets. Stakeholders require active support to adopt technologies which are commercially available in other regions. The workshop identified numerous barriers for expanding even the most commercially available technologies into new markets, including the need to establish supply chains for components and spare parts, ensure technician readiness and review and update building codes and standards.

E. Tailored solutions

33. The technology alternative landscape is diverse and fairly complex or specialized. Consequently, many of the panellists representing the industry could not say what the one best solution was without knowing more details about local priorities and conditions, since there was no universal solution. The adoption of any of the discussed alternatives will require trade-offs; an ideal replacement solution which is climate- and ozone-friendly and has the same technical characteristics as HFCs is not available.

VI. Near-term considerations and next steps

34. The ongoing transition away from HCFC in Article 5 countries presents both challenges and opportunities for the introduction of lower-GWP alternatives in the near term. Non-Article 5 countries can accelerate the adoption of such technologies even further.

35. An immediate and substantial impact could be achieved in the subsector of commercial refrigeration, in particular where HFC-404A is being used. The high leakage rates for large and medium-sized equipment in that subsector, in combination with the very high GWP of HFC-404A at nearly 4,000, allow for improvements by changing the refrigerant, even if this change is only towards a refrigerant with moderate GWP. This could be achieved in new or existing equipment and, from a technical perspective, could be undertaken immediately.

36. One important near-term opportunity is to improve the responsible use of refrigerants for the installed base by improving manufacturing and service, avoiding leaks and undertaking recovery and reuse of refrigerant during service and end of life. This is an immediate action that it is important to focus on while HFC consumption is still widespread or even continues to grow.

37. Increased awareness-raising and communication efforts can help to bring others outside the Montreal Protocol into this agenda to facilitate change. Alternatives might not be addressed as part of ongoing investments unless a much higher awareness of the need to change and possible options are communicated to a wider audience. In this regard, some participants in the workshop provided suggestions about how to clarify best sources and mechanisms to stay on top of the technology change information.

Annex

Technical issues emerging from the discussion related to the different sectors

Sector specific use

1. The refrigeration, air-conditioning and heat pumps market is dominant. It represents 86 per cent of hydrofluorocarbon (HFC) use in terms of GWP-weighted tonnes per CO₂ equivalent. It is estimated that 56 per cent of the global GWP-weighted HFC consumption is for air-conditioning and that 30 per cent is for refrigeration. Air-to-air air-conditioning systems, commercial refrigeration systems and mobile air-conditioning systems dominate the use of HFCs, representing 25 per cent, 22 per cent and 20 per cent of global warming weighted HFC use, respectively. Chillers and industrial refrigeration systems are related to another 8 per cent and 6 per cent of global warming weighted HFC use, respectively. Many of the systems in these markets have relatively high rates of leakage; more than half of total HFC consumption is for topping up refrigerant lost through gradual leakage or more major total loss incidents. The level of leakage varies considerably between different sectors. Three sectors with historically high levels of leakage are large commercial refrigeration, industrial refrigeration and mobile air conditioning.
2. Aerosols and foams together use 11 per cent of the total GWP-weighted tonnes CO₂ equivalent. In the aerosol sector, about 1.7 per cent of the total GWP-weighted tonnes CO₂ equivalent relates to technical and novelty aerosols, with another 1.1 per cent related to medical aerosols. In the foam sector, 3.9 per cent of the total GWP-weighted tonnes CO₂ equivalent is for polyurethane foam and extruded polystyrene foam represents about 3.2 per cent. The markets for HFCs in fire protection (3 per cent) and as solvent (0 per cent) are also comparatively small.

Refrigeration sector

3. In domestic refrigeration, hydrocarbon technology is already introduced in well over 50 per cent of the overall global market. The small charge sizes, low service needs and market conditions led to the transformation of this sector starting in the last century. Questions regarding the slow speed of the uptake were answered referring to specific market conditions. The technology offers high energy efficiency and is currently available on a large scale.
4. The commercial refrigeration subsector is responsible for approximately 22 per cent of the GWP-weighted use of HFCs and consists of three subsectors, namely, self-contained refrigeration cabinets, condensing units and centralized supermarket systems.
5. There is widespread use of hydrocarbons in self-contained refrigeration cabinets and smaller commercial refrigeration equipment. Equipment with a smaller capacity already uses HC-600a (isobutane) and HC-290 (propane) as alternatives. Equipment manufacturers who also charge the equipment as part of the manufacturing process stated that the costs were about the same as for HFC-based systems. While the relatively large amount of electrical devices represents a safety challenge for the manufacturers, it is something which is principally manageable without compromises in cost, functionality or safety.
6. Alternative technologies for the use in condensing units are available with CO₂ from Japanese and European suppliers, although scepticism was expressed by one panellist as to whether these would gain a large market share. HFO or HFO/HFC blends appear to offer more marketable solutions in terms of safety, cost and efficiency, while secondary cycles were considered an unlikely option for this segment.
7. Larger, centralized supermarket systems consist typically of a separate medium temperature (dairy products, meat) and a low temperature (frozen food) cooling circuit. Leak rates of up to 30 per cent per year were repeatedly mentioned for these systems. Various low-GWP alternatives are already commercially available and being used in some regions. Transcritical and cascade R-744 (CO₂) systems have been introduced in the past five years and offer very good energy efficiency as well as low GWP. Other alternatives, such as glycol secondary systems, are also being used.

8. Industrial refrigeration comprises approximately 6 per cent of global GWP-weighted HFC use. Large industrial systems already make widespread use of ammonia (R-717). The use of ammonia and CO₂ will grow. Many of the industrial systems currently using HFC are relatively small and cannot be cost effectively replaced by ammonia. The use of technologies being adopted in larger commercial systems such as R-744, or A2L refrigerants such as HFC-32, may be appropriate for small industrial systems.

9. The discussion on transport refrigeration, related to about 2 per cent of the global GWP-weighted HFC demand, concentrated mainly on the use in containers (reefers) and in road transport. Owing to the mobility of equipment, the sector requires replacement components and service availability globally and needs to operate in a very wide range of climatic conditions. Systems with CO₂ for both reefers and trucks are available on a pilot scale. Systems with HFC-32 have been announced and are expected to be introduced soon, while hydrocarbons for reefers are expected to be introduced by 2019. For CO₂ systems, currently the costs are estimated to be about 20 per cent higher than for HFC systems. Using flammable substances was assumed to lead to a cost increase of 2 to 5 per cent, with propane being at the upper end of this estimate. Moderate GWP options such as R-452A are also being introduced.

Stationary air-conditioning and heat pump sector

10. The air-conditioning sector consists of the subsectors of air-to-air systems, chillers and heating-only heat pumps, which represent 25 per cent, 8 per cent and 2 per cent of global warming weighted HFC use, respectively.

11. Chillers were seen as a subsector with good low-GWP alternatives available now or in the near future. These alternatives include HC, HFO, ammonia and water.

12. For smaller capacity mini-split systems, hydrocarbons and HFC-32 are already available as alternatives. Owing to charge size restrictions in the relevant standards, the maximum capacity of HC systems is limited. One participant advised that approximately up to 3.5 kW capacity HC-290 could be used. For larger systems, such as unitary equipment and multi-split air conditioners, no non-HFC alternatives were named. Refrigerants with the safety classification A2L for "low flammability", such as HFC-32, can be used up to a charge size of around 60 kg; this would cover a large segment of the market.

Mobile air-conditioning sector

13. Mobile air conditioning is related to 20 per cent of global GWP-weighted HFC use. The main consumption is related to the air conditioning of cars. For this application, CO₂ was tested extensively as an alternative to HFC-134a, and a number of performance enhancement technologies were introduced. HFO-1234yf was subsequently developed. At the end of 2014, about 3 million cars were on the road using HFO-1234yf.

14. Because of patent issues, HFO-1234yf is currently produced by only two manufacturers, at a cost 15–20 times that of HFC-134a, raising concerns on the side of car manufacturers. In reaction, some other refrigerant manufacturers have developed new mixtures for mobile air conditioning, such as R-445A (GWP 120). Original equipment manufacturers and suppliers have conducted extensive testing with R-445A for performance, material compatibility, flammability and risk assessment. However, these systems have not yet been commercialized. At this time, HFO-1234yf seems to be the most likely candidate to be a full-scale HFC-134a replacement. The costs are expected to decrease with greater market penetration.

15. For large mobile air-conditioning applications, CO₂ has been proposed as an alternative refrigerant that could result in significant improvements in terms of climate impact, but it is not yet clear whether it will be widely applied. Other alternatives, such as HFC-32 and HFO, are also being considered.

16. Some participants felt that ideally there should be only one solution, accepted by all car manufacturers globally. Irrespective of the selected alternative, there would be substantial cost associated with the conversion from the current refrigerant, HFC-134a. Charging and evacuations equipment would have to be developed and deployed and technician training and certification programmes conducted.

Foam sector

17. The use of HFCs for foam in GWP-weighted terms was 7 per cent of the total market, with a split between polyurethane foam and extruded polystyrene of 55 per cent and 45 per cent, respectively.

18. Low-GWP alternatives for the foam sector included flammable options (such as hydrocarbons) and non-flammables, namely, CO₂ and HFOs. Generally, the choice of type of alternative is dictated by the size and capacity of the enterprise. Cyclo-pentane has proved to be a viable technology to replace HFCs in polyurethane foam owing to the related foam properties and the cost savings, and is now employed worldwide. The main limiting factor is the high costs for conversion related to safety, particularly for small and medium-size enterprises. C-pentane-based pre-blended polyol could be an option for such enterprises, but there were still questions surrounding transport and longer-term storage, particularly in high-ambient temperatures. When insulation value is not as important for the end product, water or other agents can be used.

19. HFO product availability is still limited, and the timeline for larger-scale adoption of HFOs in developed countries might extend to 2020. As a relatively new entry, the cost is higher than currently available blowing agents (estimated at twice that of HFCs) and the quality of end products over time is still not known. Because transition for certain applications, such as spray foam, remains difficult, there is a need to look for a balance between properties and costs, for example mixing HFOs with water. There is no one technological answer spanning all types of enterprises and applications, but there are options.
